HUC 10280102 – Thompson River, Weldon River, No Creek
Water body IDs: 549, 550, 560
303(d) Listing: Escherichia coli

Total Maximum Daily Load
Implementation Strategies

for the

Thompson River Watershed
Harrison and Livingston Counties, MO

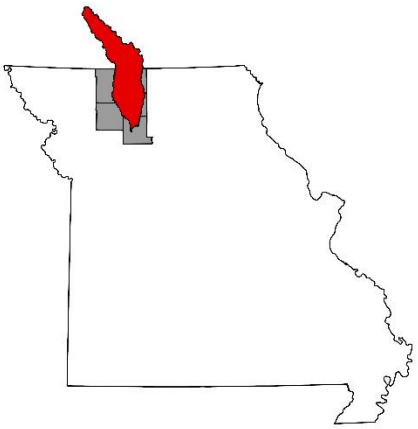
Pollutant: *Escherichia coli*

Completed: June 24, 2022

Prepared by: Water Protection Program, Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Loads (TMDL) for Thompson River, Weldon River, and No Creek

Waterbody	TMDL Development Priority
Thompson River	High
Weldon River	High
No Creek	Low



Location of watershed in Missouri

Location: Harrison and Livingston counties

8-digit Hydrologic Unit Code (HUC):[1]
10280102 – Thompson River

12-digit HUC Subwatersheds
See Section 2

Water Body Identifications (WBIDs) and Hydrologic Class:[2]
549/560/550- Class P

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Warm water habitat (aquatic life)
Drinking water supply (WBID 549 only)
Whole body contact recreation category B
Secondary contact recreation

Impaired Use:
Whole body contact recreation category B

Pollutant addressed by TMDL:
Escherichia coli (E. coli) (fecal indicator bacteria)

Identified Sources on the 2020 303(d) List:
Rural nonpoint sources

Length and Location of Impaired Segments:
Thompson River (WBID 549): 70.6 miles, from mouth to Township 67N, Range 26W
No Creek (WBID 550): 28.7 miles, from mouth to Township 62N, Range 23W
Weldon River (WBID 560): 43.4 miles, from mouth to Township 62N, Range 24W

---

[1] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS 2019). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain permanent flow even in drought periods.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

TABLE OF CONTENTS

Figures

Tables

1. Introduction

A total maximum daily load (TMDL) report for Thompson River, Weldon River, and No Creek addresses elevated *Escherichia coli* (*E. coli*) bacteria concentrations that resulted in the water body's placement on Missouri's 303(d) List of Impaired Waters. The TMDLs established for the impaired water bodies represent the *E. coli* loading capacity for each stream, which is the maximum amount of a pollutant that a water body can assimilate and still attain and maintain water quality standards. Watershed characteristics and *E. coli* loading targets can be found in the TMDL report, which is available on the Missouri Department of Natural Resources' website at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls. Although this implementation document is drafted primarily to implement the goals of the *E.coli* TMDL, this document also addresses nutrient loading. Many of the practices suggested in this document will reduce both *E. coli* and nutrient loading. Questions regarding the TMDLs may be sent via email to tmdl@dnr.mo.gov or by calling the Department's Watershed Protection Section at 573-751-5723.

This implementation strategies document is a companion to the TMDL report and suggests actions that will reduce pollutant loading in order to meet the loading capacities established in the TMDL document. The goals of the TMDLs are to attain and maintain designated uses in the water bodies. The whole body contact recreation category B use is impaired in Thompson River, Weldon River, and No Creek due to elevated *E. coli* concentrations in the rivers.

This document neither prescribes nor prohibits any specific practices or technologies for reducing pollutant loading in the impaired water bodies and is not intended to serve as the sole means of remediation and restoration. However, the Department recognizes that technical guidance and support are critical to achieving the goals of any TMDL. Therefore, while the TMDL calculates the maximum pollutant loading that the impaired water bodies can assimilate and still attain and maintain water quality standards, this strategies document provides additional information to assist in meeting the TMDL loading goals including: pollutant reduction strategies, example calculations of pollutant reductions, potential participants in the watershed, and funding sources. Because the TMDL addresses pollutant loading from all potential sources in the watershed, this strategies document provides guidance for meeting the loading targets assigned to both point and nonpoint sources.[4] Point source pollutant loading controls are implemented primarily through the Missouri State Operating Permit program.[5] Effluent limits are established in facility permits based on the assumptions and requirements of the wasteload allocations and other recommendations in the TMDL documents. Cost-share loans are available from the State Revolving Fund and are administered through the Department's Financial Assistance Center to help finance facility upgrades that are necessary to meet more stringent effluent limits.

Watershed management practices that reduce nonpoint source pollutant loading are conducted voluntarily by interested stakeholders and landowners within the watersheds. In accordance with Section 319 of the federal Clean Water Act, the U.S. Environmental Protection Agency (EPA) provides funding for nonpoint source pollutant load reduction practices. Section 319 nonpoint source

[4] Point and nonpoint sources are defined and discussed in Sections 5.1 and 5.2 of the TMDL report for Thompson River, Weldon River, and No Creek.

[5] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees

subgrants are administered through Missouri's Section 319 program to assist organizations with watershed planning or implementation of activities as described in a Nine Element Watershed Management Plan (or alternative plan under certain specific conditions) that has been accepted by the Department and EPA. The Nine Key Elements of a Watershed Management Plan are provided in Appendix A. More information on Missouri's Section 319 subgrant program is available at: dnr.mo.gov/water/what-were-doing/nonpoint-source-pollution-section-319. Additional cooperating organizations and sources of funding are provided in Section 11 of this document.

2. Watershed Characteristics

Thompson River, Weldon River, and No Creek are located in northcentral Missouri within the Thompson River subbasin, which is cataloged by the U.S. Geological Survey (USGS) as the 8-digit hydrologic unit code (HUC) 10280102. The Thompson River subbasin is composed of 32, 12-digit HUC subwatersheds totaling 2,201 square miles (Table 1). Within this subbasin, the area of the Weldon River watershed is 155.8 square miles and the No Creek watershed is 110.6 square miles. Thompson River originates in Adair County, Iowa and flows south for 175.6 miles to the Grand River in Missouri. The extent of the Missouri portion of Thompson River (WBID 549) is 70.6 miles. Weldon River (WBID 550) and No Creek (WBID 560) are both tributaries of Thompson River. Weldon River originates in Decatur County, Iowa and flows south for 57.7 miles to Thompson River. The extent of the Missouri segment is 43.4 miles. No Creek is located entirely in Missouri and extends 28.7 miles northeast from the confluence at Thompson River.

Table 1. 12-digit HUCs in the Thompson River Watershed

12-digit HUCs	Name
10280102-0602	Indian Creek
10280102-0603	Jefferies Creek-Thompson River
10280102-0604	Coal Creek-Thompson River
10280102-0605	Panther Creek
10280102-0606	Brushy Creek-Thompson River
10280102-0704	Brush Creek-Little River
10280102-0806	Lick Branch-Weldon River
10280102-0901	Big Branch-Weldon River
10280102-0902	West Muddy Creek
10280102-0903	Wildcat Creek-Weldon River
10280102-0904	Middle Creek-Weldon River
10280102-1001	Sandy Creek
10280102-1002	Trail Creek
10280102-1003	Martin Creek-Thompson River
10280102-1004	Cat Creek-Thompson River
10280102-1005	Fox Creek-Sugar Creek
10280102-1006	Racoon Creek
10280102-1007	Sugar Creek
10280102-1008	Lost Creek-Thompson River
10280102-1101	Upper Muddy Creek

12-digit HUCs	Name
10280102-1102	Middle Muddy Creek
10280102-1103	Lower Muddy Creek
10280102-1201	East and West Forks Honey Creek
10280102-1202	Upper Honey Creek
10280102-1203	Lower Honey Creek
10280102-1301	Headwaters No Creek
10280102-1302	Crooked Creek
10280102-1303	No Creek
10280102-1401	Hickory Creek
10280102-1402	Gees Creek
10280102-1403	Wolf Creek-Thompson River
10280102-1404	Thompson River

Thompson River originates in the Rolling Loess Prairies ecoregion. This ecoregion is defined by thin loess deposits (less than 25 feet) and open low hills. Eighty-five percent of Thompson River watershed, and all of Weldon River and No Creek watersheds, are situated within the Loess and Till Plains Level IV. The topography in this region is varies from flat to moderately hilling and there tends to be deeper loess deposits than the rolling Loess Prairies ecoregion, (MoRAP 2005).

Land cover types present in Thompson, Weldon, and No Creek watersheds are summarized in Table 2, 3, and 4, respectively. Figure 1 depicts the distribution of the land cover types throughout the watershed. Agricultural areas (cropland, grassland, and pasture) cover approximately 70 percent of the Missouri side of the Thompson River watershed. Within the larger watershed, agricultural areas cover 63 percent of the Missouri side of the Weldon River watershed and over 80 percent of the No Creek Watershed.

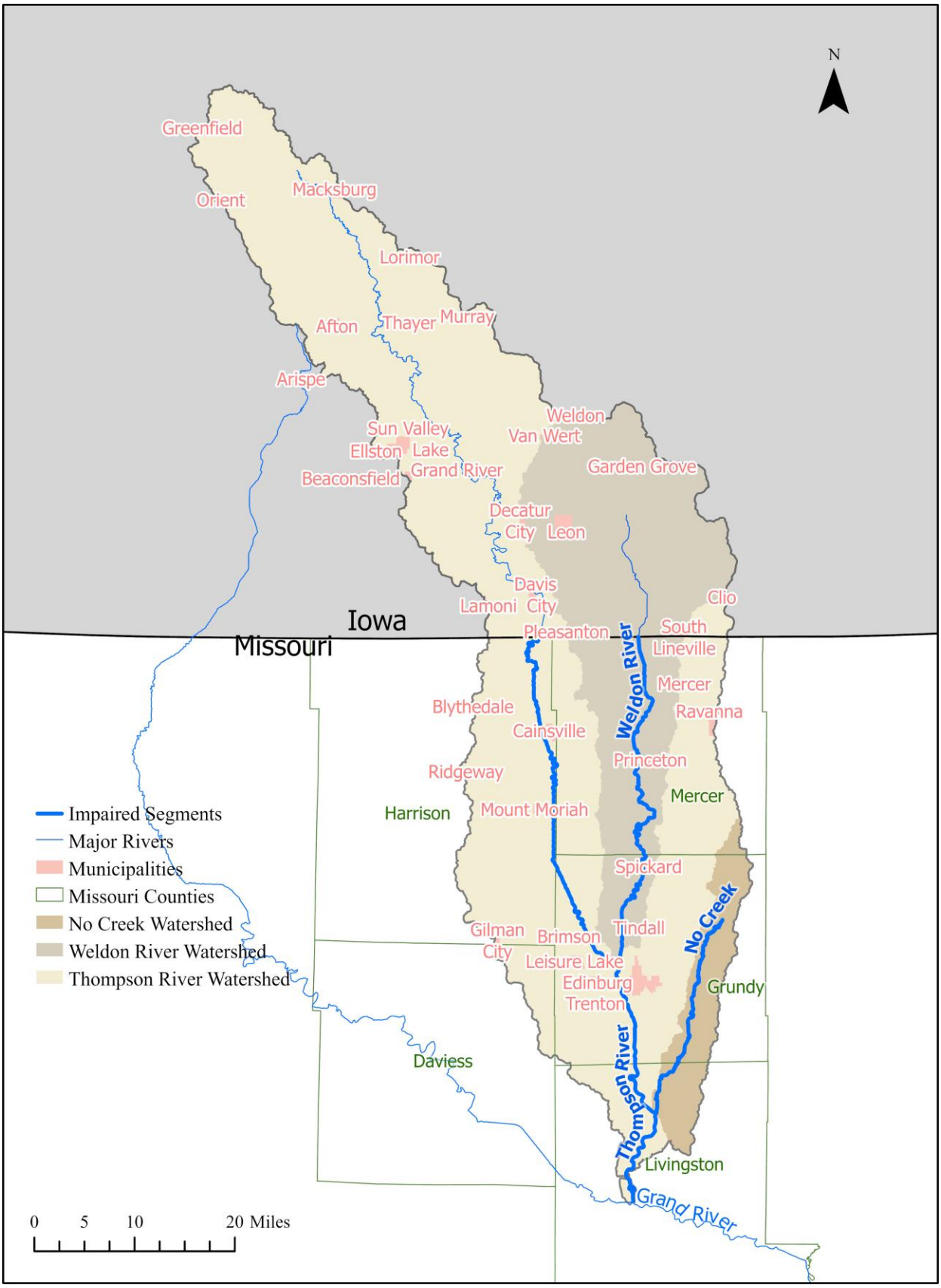


Figure 1. Location of Thompson, Weldon, and No Creek Watersheds

Table 2. Land Cover in the Thompson River Watershed

Land Cover Type	Total Watershed		Missouri Only	
	Area (Square Miles)	Percent	Area (Square Miles)	Percent
Developed, High Intensity	0.848	0.04%	0.487	0.04%
Developed, Medium Intensity	5.464	0.25%	2.349	0.21%
Developed, Low Intensity	41.283	1.88%	17.209	1.56%
Developed, Open Space	46.112	2.09%	27.313	2.47%
Barren	2.246	0.10%	1.702	0.15%
Cultivated Crops	706.105	32.08%	343.519	31.06%
Hay/Pasture	896.857	40.75%	435.830	39.40%
Shrub/Herbaceous	13.369	0.61%	6.856	0.62%
Forest	431.688	19.61%	235.146	21.26%
Wetlands	40.187	1.83%	28.085	2.54%
Open Water	16.898	0.77%	7.666	0.69%
Totals	2,201.057	100.00%	1,106.163	100.00%

Table 3. Land Cover in the Weldon River Watershed

Land Type	Total Watershed		Missouri Only	
	Area Square Miles	Percent	Area Square Miles	Percent
Developed, High Intensity	0.202	0.04%	0.089	0.04%
Developed, Medium Intensity	1.252	0.22%	0.460	0.21%
Developed, Low Intensity	11.309	2.00%	3.494	1.62%
Developed, Open Space	11.127	1.96%	5.744	2.67%
Barren	0.593	0.10%	0.460	0.21%
Cultivated Crops	140.418	24.78%	50.178	23.28%
Hay/Pasture	251.675	44.42%	86.790	40.27%
Shrub/Herbaceous	4.588	0.81%	1.591	0.74%
Forest	132.154	23.32%	59.225	27.48%
Wetlands	9.112	1.61%	5.791	2.69%
Open Water	4.197	0.74%	1.680	0.78%
Totals	566.626	100.00%	215.503	100.00%

Table 4. Land Cover in the No Creek Watershed

Land Cover Type	Area Square miles	Percent
Developed, High Intensity	0.013	0.01%
Developed, Medium Intensity	0.137	0.12%
Developed, Low Intensity	1.764	1.60%
Developed, Open Space	2.505	2.27%
Barren Land	0.016	0.01%
Cultivated Crops	43.338	39.21%

Land Cover Type	**Area Square miles**	**Percent**
Hay/Pasture	46.558	42.13%
Shrub and Herbaceous	0.415	0.38%
Forest	10.900	9.86%
Wetlands	4.580	4.14%
Open Water	0.295	0.27%
Totals	110.522	100.00%

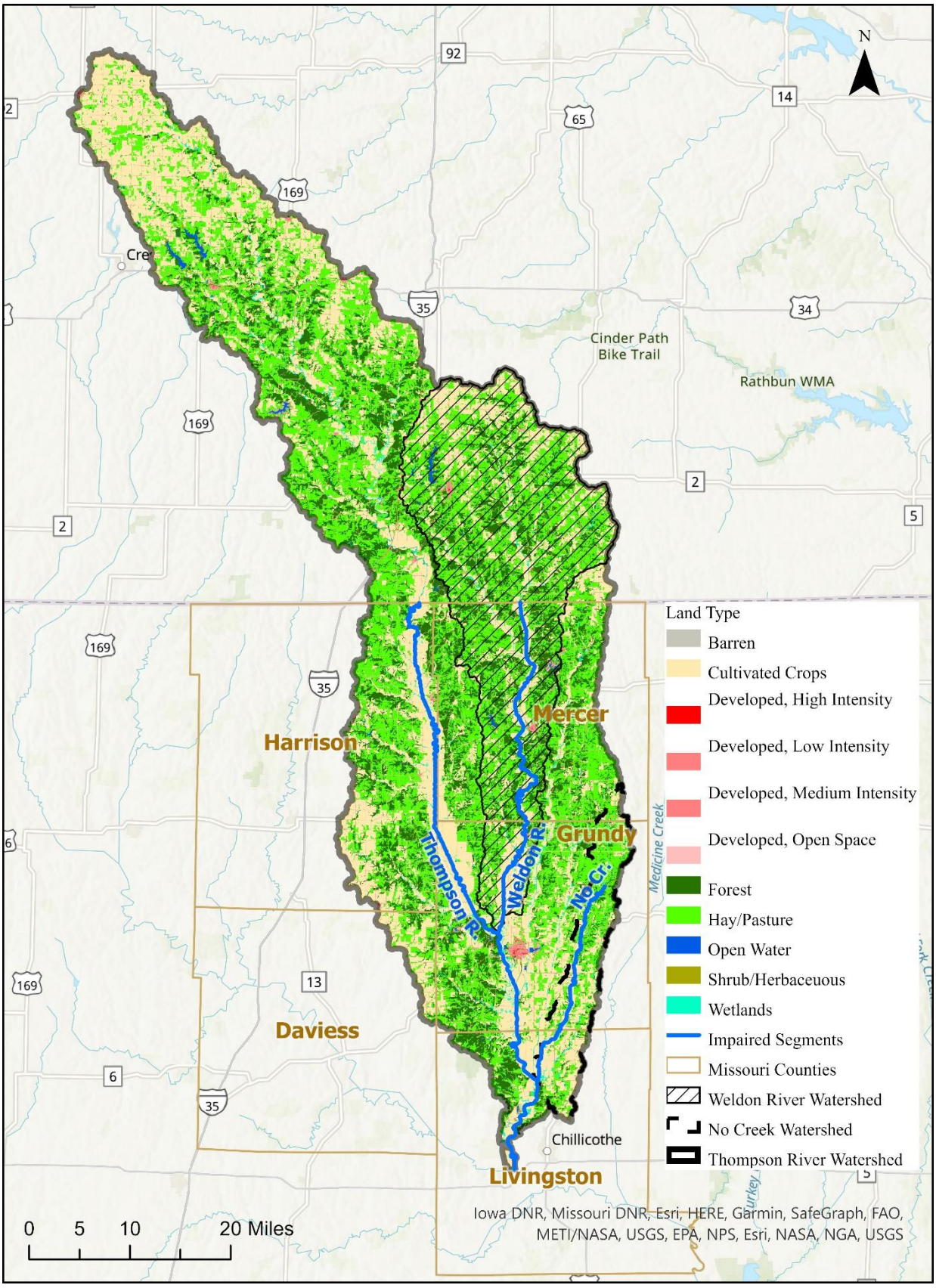


Figure 2. Land Cover in the Thompson River, Weldon River, and No Creek Watershed

3. Water Quality Impairments

Water quality criteria are limits on certain chemicals or conditions in a water body established to protect designated uses. The whole body contact recreation category B designated use is impaired due to high *E. coli* bacteria concentrations in Thompson River, Weldon River, and No Creek. Whole body contact recreation includes activities that involve direct human contact with waters of the state to the point of complete body submergence (10 CFR 20-7.031(1)(C)2.A.). During such activities, such as swimming, accidental ingestion of the water may occur and there is direct contact to sensitive body organs, such as the eyes, ears, and nose. Whole body contact category A applies to waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreation uses by the public (10 CSR 20-7.031(1)(C)2.A.(I)). Whole body contact category B applies to waters designated for whole body contact recreation not contained within category A (10 CSR 20-7.031(1)(C)2.A.(II)). Secondary contact recreation, which includes activities such as boating, fishing, and wading, are activities that may result in contact with the water that is either incidental or accidental and the probability of ingesting appreciable quantities of water is minimal (10 CSR 20-7.031(1)(C)2.B.). The secondary contact recreation uses are not impaired in Thompson River, Weldon River, and No Creek.

E. coli are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of potential fecal contamination and risk of pathogen-induced illness to humans. In accordance with Missouri's 2020 Listing Methodology Document, the whole body contact recreation category B designated uses for Thompson River, Weldon River, and No Creek are impaired because the geometric means of *E. coli* samples collected during the recreational season (April-October) were greater than 206 colony forming units (cfu) per 100 milliliters (mL) in the most recent three years having available data with five or more samples.[6] Sufficient data consistent with the assessment methodology are available to support these listings as summarized in Table 5 and Figure 3. As shown, in years with five or more samples *E. coli* concentrations exceeded the geometric mean of 206 cfu/100 mL in Thompson River in 2016-2019, No Creek in 2016-2020, and Weldon River in 2019.

Table 5. Summary of Recreational *E. coli* Data for the Impaired Water Bodies

Water Body	Recreational Season	Number of Samples	Max (cfu/100 mL)	Min (cfu/100 mL)	Geometric Mean* (cfu/100 mL)
Thompson River	2020	4	23	18,000	386.25
	2019	5	100	20,000	**635.19**
	2018	11	31	5,000	**453.59**
	2017	11	52	20,000	**389.54**
	2016	11	52	6,500	**722.70**
No Creek	2020	5	180	3,200	**679.13**
	2019	7	150	2,000	**271.70**
	2018	7	46	13,000	**325.22**
	2017	7	150	2,500	**607.15**
	2016	7	180	17,000	**700.64**

[6] Listing Methodology documents are available online at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls

Water Body	Recreational Season	Number of Samples	Max (cfu/100 mL)	Min (cfu/100 mL)	Geometric Mean* (cfu/100 mL)
Weldon River	2020	4	60	32,000	455.39
	2019	5	16	50,000	**686.36**
	2018	4	33	12,000	381.27
	2017	4	29	450	153.01
	2016	4	120	4,400	599.72
	2015	4	110	37,000	3,170.93
	2014	4	340	5,600	730.55
	2013	5	58	510	**131.86**
	2012	4	92	1,800	292.17
	2011	4	25	30,000	236.26
	2010	4	11	15,000	262.10
	2009	4	34	500	187.76
	2008	3	670	7,200	1,744.21
	2007	5	10	280	**80.66**

* Bold values indicate geometric means calculated from a sufficient number of samples that can be used for assessment purposes

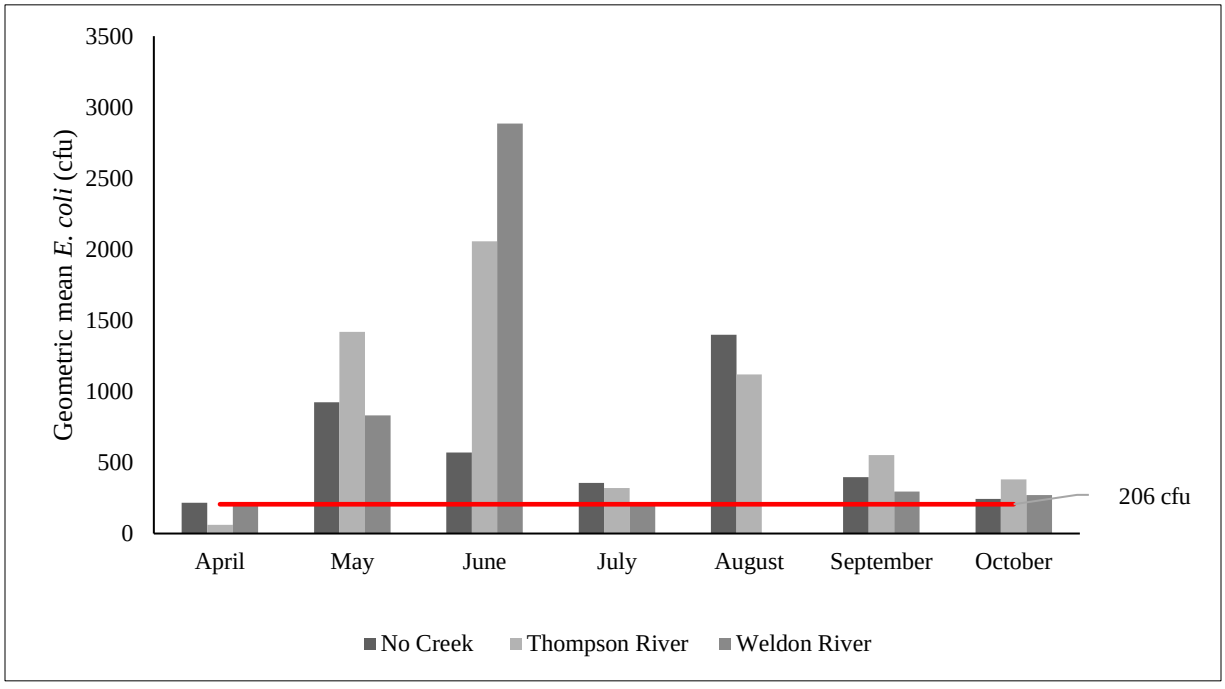


Figure 3. *E. coli* Geometric Means by Month (Includes years with <5 samples)

Causes and Sources of Pollutant Loads

4.1 Agricultural Areas

Croplands, pasturelands, and low-density animal feeding operations are potential sources of bacteria in surface waters. Bacteria are transported in runoff from areas fertilized with animal manure and where livestock are present. Runoff can result from precipitation or excessive irrigation. Section 640.760 Revised Statutes of Missouri (RSMo) establishes setback distances for surface application of liquefied manure from a confined animal feeding operation (CAFO) by a third party.[7] Pursuant to Section 640.760 RSMo, the Department may enforce stricter setbacks. Soil and Water Conservation Districts provide funding and guidance for the development of nutrient management plans for private lands. Areas where nutrient management plans guide manure application and where best management practices are used to reduce soil erosion contribute less bacteria to surface waters than unmanaged areas. Although grazing areas are typically well vegetated, livestock tend to congregate near feeding and watering areas and create barren areas that are susceptible to erosion (Sutton 1990). Livestock that are not excluded from streams deposit manure and thus bacteria directly into waterways.

As shown previously in Table 2, 3, and 4 and Figure 2, the Thompson River, Weldon River, and No Creek watersheds are dominated by hay and pasture, with a total of 896.9 square miles potentially grazed by livestock in the Thompson watershed. Aside from livestock present in permitted CAFOs, the exact type and number of livestock present in the Thompson, Weldon, and No Creek watersheds are unknown. An estimate of the number of cattle in the Missouri portion of the watershed was calculated by using the available land cover data and county cattle population numbers provided in the U.S. Department of Agriculture's 2017 Census of Agriculture (NASS 2017). Using the total number of cattle in Mercer, Grundy, Livingston, Daviess, and Harrison counties and the proportion of each county's area of pastureland in the watershed to the total area of pastureland in each county, it is estimated that there are 76 cows per square mile of grassland or pasture in the Thompson River, Weldon River, and No Creek watersheds (Table 6).[8] This indicates that there are 33,093 cows in the Thompson watershed, 6,590 cows in the Weldon watershed, and 3,535 cows in the No Creek watershed.

Table 6. 2017 Cattle Population Estimates for Pasture Areas in the Missouri Side of the Thompson River Watershed

County	Cattle No.	Pastureland (Sq. Mi.)	Pastureland in Watershed (Sq. Mi.)	Pastureland in Watershed/ Total Pastureland	Watershed Cattle No.
Mercer	20,603	219	170.53	0.78	16,013.08
Grundy	20,992	165	137.13	0.83	17,474.01
Livingston	15,064	149	22.22	0.15	2,243.11
Daviess	25,202	227	10.02	0.04	1,114.48
Harrison	43,136	338	95.94	0.28	12,261.10
Total Estimated Cattle in the Thompson River Watershed					33,092.70

[7] Section 640.760 RSMo setback distances are: 50 feet from a property boundary, 300 feet from any public drinking water lake, 300 feet from any public drinking water intake structure, 100 feet from any perennial and intermittent streams without vegetation abutting such streams, and 35 feet from any perennial and intermittent streams with vegetation abutting such streams.

[8] This analysis assumes all areas identified as grassland or pasture are being used for cattle grazing and that cattle are evenly distributed among those areas. Additionally, although some animals may be confined in some areas, for purposes of this estimation the entire cattle population was assumed to be grazing on pasture areas.

Cattle per Square Mile of Pastureland	75.93

Other types of livestock such as horses and sheep may also be contributing bacteria loads in the Thompson River watershed. The number and distribution of other animals in the watershed is unknown.

4.2 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the attenuation of pollutants in runoff. Land cover within 100 feet of streams in the Missouri side of the Thompson River, Weldon River, and No Creek watersheds is presented in Tables 7, 8, and 9. Agricultural areas constitute around 34 percent of the riparian corridors of streams in the Thompson and Weldon watersheds and about 41 percent of the riparian corridors in the No Creek watershed. These areas may be more susceptible to *E. coli* loading. Over 40 percent of the riparian corridors in the Thompson and Weldon watershed are forested and over 20 percent of the riparian corridors in No Creek watershed are forested. This indicates that some *E. coli* transported from adjacent cropland and pasture lands into those areas may be intercepted before it enters the streams.

Table 7. Land Cover in Riparian Corridors in the Missouri side of the Thompson River Watershed

Land Cover Type	Riparian Corridor Land Cover Type Area	
	Area Square Miles	Percent
Developed, High Intensity	0.006	0.01%
Developed, Medium Intensity	0.062	0.09%
Developed, Low Intensity	0.422	0.63%
Developed, Open Space	0.868	3.52%
Barren	0.380	0.56%
Cultivated Crops	10.817	16.06%
Hay/Pasture	12.526	18.59%
Shrub/Herbaceous	0.41	0.61%
Forest	28.31	42.02%
Wetlands	9.696	14.39%
Open Water	2.369	3.52%
Totals	67.366	100.00%

Table 8. Land Cover in Riparian Corridors in the Missouri side of the No Creek Watershed

Land Cover Type	Riparian Corridor Land Cover Type Area	
	Square Miles	Percent
Developed, High Intensity	0	0.00%
Developed, Medium Intensity	0.003	0.05%

Land Cover Type	Riparian Corridor Land Cover Type Area	
	Square Miles	Percent
Developed, Low Intensity	0.044	0.74%
Developed, Open Space	0.073	1.23%
Barren	0	0.00%
Cultivated Crops	0.785	13.10%
Hay/Pasture	1.650	27.51%
Shrub/Herbaceous	0.011	0.18%
Forest	1.672	27.88%
Wetlands	1.742	29.06%
Open Water	0.016	0.26%
Totals	5.996	100.00%

Table 9. Land Cover in Riparian Corridors in the Missouri Side of the Weldon River Watershed

Land Type	Riparian Corridor Land Cover Type Area	
	Square Mile	Percent
Developed, High Intensity	0.003	0.02%
Developed, Medium Intensity	0.017	0.12%
Developed, Low Intensity	0.09	0.65%
Developed, Open Space	0.181	1.31%
Barren	0.125	0.90%
Cultivated Crops	2.336	16.87%
Hay/Pasture	2.357	17.02%
Shrub/Herbaceous	0.08	0.58%
Forest	6.313	45.59%
Wetlands	1.745	12.60%
Open Water	0.6	4.33%
Totals	13.846	100.00%

5. Existing Loads and Needed Reductions

5.1 *E. coli* Bacteria

As mentioned previously, the whole body contact recreation category B designated use is impaired due to high *E. coli* bacteria concentrations in Thompson River, Weldon River, and No Creek. The *E. coli* TMDLs for Thompson River, Weldon River, and No Creek are represented by load duration curves that quantify the loading capacity at all possible flows. Tables 10, 11, and 12 summarize the TMDLs at selected flows and the load reductions that are needed to meet the TMDLs displayed in Section 7 of the TMDL document. The load reductions were calculated based on the geometric mean of observed *E. coli* data recorded during each selected flow condition. As shown, *E. coli*

concentrations do not exceed water quality criterion during low flow conditions in any of the streams. In No Creek, concentrations are exceeded in dry to high flow condition; in Thompson River, concentrations are exceeded until mid-range to high flow conditions; and in Weldon River, they are only exceeded in moist conditions and high flows.

Table 10. Thompson River TMDL and Needed Reductions

Percent of Time Flow is Equal or Exceeded	Flow Condition	Median Flow (cfs)	TMDL (counts/day)	Existing Load (counts/day)	Needed Reduction (counts/day)	Needed Reduction (%)	Existing Concentration (cfu/100mL)
100-90	Low flow	36.62	1.49E+11	1.40E+11	0.00E+00	0.00%	156
90-60	Dry conditions	120.08	4.88E+11	4.78E+11	0.00E+00	0.00%	163
60-40	Mid Range	377.78	1.53E+12	2.87E+12	1.33E+12	46.46%	310
40-10	Moist Conditions	1,209.15	4.91E+12	2.37E+13	1.88E+13	79.28%	801
10-0	High Flow	6,620.77	2.69E+13	1.12E+15	1.10E+15	97.61%	6,932

Table 11. No Creek TMDL and Needed Reductions

Percent of Time Flow is Equal or Exceeded	Flow Condition	Median Flow (cfs)	TMDL (counts/day)	Existing Load (counts/day)	Needed Reduction (counts/day)	Needed Reduction (%)	Existing Concentration (cfu/100mL)
100-90	Low flow	1.34	6.77E+09	3.24E+09	0.00E+00	0.00%	99
90-60	Dry conditions	4.70	2.37E+10	5.39E+10	3.02E+10	56.02%	468
60-40	Mid Range	14.95	7.54E+10	4.06E+11	3.31E+11	81.44%	1,110
40-10	Moist Conditions	45.80	2.31E+11	3.59E+11	1.29E+11	35.78%	321
10-0	High Flow	317.00	1.60E+12	3.35E+12	1.76E+12	52.37%	433

Table 12. Weldon River TMDL and Needed Reductions

Percent of Time Flow is Equal or Exceeded	Flow Condition	Median Flow (cfs)	TMDL (counts/day)	Existing Load (counts/day)	Needed Reduction (counts/day)	Needed Reduction (%)	Existing Concentration (cfu/100mL)
100-90	Low flow	9.39	3.59E+10	4.60E+10	1.01E+10	21.89%	200
90-60	Dry conditions	30.79	1.18E+11	7.71E+10	0.00E+00	0.00%	102
60-40	Mid Range	96.86	3.71E+11	2.05E+11	0.00E+00	0.00%	86
40-10	Moist Conditions	310.03	1.19E+12	5.35E+12	4.16E+12	77.82%	705
10-0	High Flow	1,697.56	6.50E+12	1.07E+15	1.07E+15	99.40%	25,862

5.2 Nitrogen and Phosphorus

Missouri's water quality standards do not establish nutrient criteria for streams. However, nutrient load reductions are a statewide priority, and many of the nonpoint source management measures that reduce *E. coli* loading also reduce nitrogen and phosphorus loading. Excessive nitrogen and phosphorus loading can lower the quality of ground and surface water. In high quantities, nitrogen has the potential to harm animals and humans. Phosphorus leachate in runoff or attached to sediment particles entering the surface water contributes to excessive algae growth causing low oxygen levels in surface water that impairs aquatic life and contributes to bad tasting drinking water (NRCS 2013).

Nutrient targets used for load duration curves are based on EPA, Region 7 Regional Technical Assistance Group (RTAG) benchmark values. These benchmark values are expected to be protective of Missouri's designated uses, but are not water quality criteria codified in Missouri's Water Quality Standards regulations at 10 CSR 20-7.031. In the absence of Missouri-specific nutrient criteria for streams, these targets are provided only as guidance to assist watershed planning activities. Thompson River, Weldon River, and No Creek are not currently identified as impaired due to nutrients and no specific nutrient reductions are required for attainment of existing applicable water quality standards. Groups developing their own watershed plans may determine that alternative, scientifically defensible, nutrient targets are appropriate for maintaining or attaining water quality standards in the water bodies. If TMDLs are developed in the future to address nutrient pollution in Thompson River, Weldon River, or No Creek, then the load allocations established in those approved TMDLs should serve as the targets for watershed planning and nonpoint source nutrient reduction efforts.

Tables 13, 14, and 15 summarize the nitrogen and phosphorous loads at selected flows. The load reductions were calculated based on the 95th percentile of observed total nitrogen and total phosphorous that exceeded the RTAG recommendation of 0.9 milligram per liter (mg/L) of total nitrogen and 0.075 mg/L total phosphorous. The data were collected by USGS from 2001 to 2020 at Thompson River near Mount Mariah, No Creek near Dunlap, and Weldon River near Princeton.

Table 13. Total Nitrogen and Phosphorus Loads and Recommended Reductions for Thompson River.

Nutrient	Percent of Time Flow is Equal or Exceeded	Flow Condition	Median Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)	Existing Concentration (mg/L)
TN	100-90	Low flow	36.6	178	511	333	65.2%	2.6
	90-60	Dry conditions	120.1	583	2,414	1,831	75.8%	3.7
	60-40	Mid Range	377.9	1,834	11,855	10,021	84.5%	5.8
	40-10	Moist Conditions	1,209.1	5,870	109,818	103,948	94.7%	16.8
	10-0	High Flow	6,620.8	32,141	434,449	402,308	92.6%	12.2
TP	100-90	Low flow	36.6	15	59	44	74.84%	0.3
	90-60	Dry conditions	120.1	49	276	227	82.38%	0.4
	60-40	Mid Range	377.8	153	930	777	83.57%	0.5
	40-10	Moist Conditions	1,209.1	489	18,100	17,593	97.29%	2.8
	10-0	High Flow	6,620.8	2,678	106,940	104,262	97.50%	3.0

Table 14. Total Nitrogen and Total Phosphorus Loads and Recommended Reductions for No Creek

Nutrient	Percent of Time Flow is Equal or Exceeded	Median Flow Condition	Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)	Existing Concentration (mg/L)
TN	100-90	Low flow	1.3	7	25	18	73.4%	3.4
	90-60	Dry conditions	4.7	23	121	98	81.1%	4.8
	60-40	Mid Range	15.0	73	313	240	76.8%	3.8

Nutrient	Percent of Time Flow is Equal or Exceeded	Median Flow Condition	Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)	Existing Concentration (mg/L)
	40-10	Moist Conditions	45.8	222	1,833	1,611	87.9%	7.4
	10-0	High Flow	317.0	1,539	34,410	32,871	95.5%	20.1
TP	100-90	Low flow	1.3	1	2	1	70.4%	0.3
	90-60	Dry conditions	4.7	2	12	10	84.5%	0.5
	60-40	Mid Range	15.0	6	30	24	80.2%	0.4
	40-10	Moist Conditions	45.8	19	229	210	91.9%	0.9
	10-0	High Flow	317.0	128	6,908	6,780	98.1%	4.0

Table 15. Total Nitrogen and Phosphorus Loading and Recommended Reductions for Weldon River

Nutrient	Percent of Time Flow is Equal or Exceeded	Median Flow Condition	Flow (cfs)	Target Load (lbs/day)	Existing Load (lbs/day)	Needed Reduction (lbs/day)	Needed Reduction (%)	Existing Concentration (mg/L)
TN	100-90	Low Flow	9.4	46	72	26	36.4%	1.4
	90-60	Dry Conditions	30.8	149	258	108	42.0%	1.6
	60-40	Mid Range	96.9	470	1,563	1,093	69.9%	3.0
	40-10	Moist Conditions	310.0	1,505	16,308	14,803	90.8%	9.8
	10-0	High Flow	1,697.6	8,241	142,812	134,571	94.2%	15.6
TP	100-90	Low Flow	9.4	4	5	2	28.3%	0.1
	90-60	Dry Conditions	30.8	12	42	30	70.4%	0.3
	60-40	Mid Range	96.9	39	181	142	78.4%	0.3
	40-10	Moist Conditions	310.0	125	3,526	3,401	96.4%	2.1
	10-0	High Flow	1,697.6	687	65,123	64,436	98.9%	7.1

6. Point Source Implementation

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require permit conditions to be consistent with the assumptions and requirements of TMDL wasteload allocations and other recommendations in the TMDL documents. How these conditions are expressed can vary depending upon the pollutant and nature of the discharge. Although TMDLs are required to be written for daily time increments, permit effluent limits may be written in a form that derives from and complies with applicable water quality standards that use any time measure (40 CFR 122.44(d)(1)(vii)(A) and EPA 2006). The Department's permit writers have discretion for how TMDL wasteload allocations are expressed in a permit and for determining appropriate implementation schedules. Permit writers should consult available permit writing handbooks and technical support documents to determine appropriate limits.[9] Although wasteload allocations are often specified for individual facilities, in some cases, it may be appropriate

[9] The Department maintains a Water Pollution Control Permit Manual to provide guidance to permit writing staff and is available online at dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees/wastewater. Additionally the EPA maintains a National Pollutant Discharge Elimination System (NPDES) Permit Writers' Manual online at epa.gov/npdes/npdes-permit-writers-manual.

for pollutant loadings to be shifted between the individual facilities during permitting as long as the sum of the wasteload allocations remains unchanged and the loading capacity is not exceeded. In no case does a TMDL wasteload allocation allow for permit limits that exceed water quality standards. If water quality standard revisions result in criteria more stringent than an established TMDL wasteload allocation, then the more stringent criteria should be used in deriving the permit limits.[10] Information regarding the Department's permitting process is available online at dnr.mo.gov/env/wpp/permits/index.html or by calling the Department's Operating Permit Section at 573-522-4502.

Table 16 lists the types of point sources in the Thompson River, Weldon River, and No Creek watersheds that should be addressed in order to achieve the TMDL wasteload allocation targets. As noted in the TMDL, nine municipal wastewater discharges are present in these watersheds that are potential contributors of *E. coli* loading. Currently Princeton Wastewater Treatment Facility and Trenton Municipal Utilities Wastewater Treatment Plant disinfect their effluent. None of the other facilities disinfect their effluent, however appropriate *E. coli* limits or schedules of compliance are provided in all state operating permits.

Table 16. Point Source *E.coli* Load Reduction Strategies

Type	Objective	Strategies
Municipal and domestic wastewater dischargers	Meet wasteload allocations assigned in Section 8.1 of TMDL report	• Appropriate *E. coli* permit limits • Disinfection • Consider no discharges option • Reduce occurrences of sanitary sewer overflows
Concentrated Animal Feeding Operations (CAFOs)	Meet wasteload allocations assigned in Section 8.3 of the TMDL report	• Maintain no discharge • Land apply waste according to permitted conditions • Nutrient management plans to manage manure application rates
Illicit straight pipe discharges	Illegal discharges and therefore should be eliminated from the watershed	• Report known discharges to local county health departments

7. Nonpoint Source Implementation

7.1 Focus Areas for Nonpoint Source Management

Areas that contribute the highest nonpoint source loading to Thompson River, Weldon River, and No Creek should be prioritized for best management practices. Typical focus areas are those where water bodies are adjacent to cropland and pastureland. Nonpoint source management measures that reduce nitrogen and phosphorus loading are often also effective *E. coli* reduction measures. The focus areas

[10] Federal regulations at 40 CFR 131.21, also known as the "Alaska Rule," require water quality standards to be approved by the EPA before they can be used for Clean Water Act purposes (i.e., water quality-based effluent limitations or TMDLs).

for nonpoint source management provided in Table 17 and Figure 4 are based on estimated nitrogen and phosphorous loads because *E. coli* data are only available at select sample sites. The relative nutrient loading rates per acre are provided for informational purposes only. Best management practices for nonpoint source load reductions will benefit water quality in Thompson River, Weldon River, and No Creek when conducted in any area of their respective watersheds. Landowners and watershed groups seeking Soil and Water Conservation and Clean Water Act Section 319 grant funds should prioritize activities based on local interest and potential for success.

Nitrogen and phosphorus loading from each 12-digit hydrologic unit code (HUC-12) watershed in Missouri was estimated using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Land cover, number of animals, and septic sewer system inputs are based on information downloaded from the STEPL Input Data Server. The input data server currently uses 2011 land use area distribution and 2012 agricultural animal count. Nitrogen loading rates in each HUC-12 watershed range from 4.54 to 6.25 pounds per year per acre (lbs/year)/acre. Phosphorus loading rates in each HUC-12 watershed range from 0.59 to 0.92 (lbs/year)/acre. Table 17 presents the proportions of nonpoint nitrogen and phosphorous loading to total area in each HUC-12. Ranks based on relative loading are illustrated in Figure 4.

Table 17. Estimated Nitrogen and Phosphorus Loading by HUC-12 Watershed

HUC-12	HUC-12 name	Nitrogen (lbs/year)/acre	Phosphorus (lbs/year)/acre	Rank
102801020602	Indian Creek	6.144	0.676	High
102801020603	Jefferies Creek-Thompson River	4.673	0.720	Low
102801020604	Coal Creek-Thompson River	5.026	0.652	Low
102801020605	Panther Creek	5.518	0.668	Medium
102801020606	Brushy Creek-Thompson River	5.289	0.727	Medium
102801020704	Brush Creek-Little River	5.242	0.622	Medium
102801020806	Lick Branch-Weldon River	5.029	0.646	Low
102801020901	Big Branch-Weldon River	4.632	0.605	Low
102801020902	West Muddy Creek	5.589	0.633	High
102801020903	Wildcat Creek-Weldon River	4.600	0.595	Low
102801020904	Middle Creek-Weldon River	5.582	0.857	High
102801021001	Sandy Creek	5.263	0.603	Medium
102801021002	Trail Creek	5.294	0.682	Medium
102801021003	Martin Creek-Thompson River	5.525	0.744	High
102801021004	Cat Creek-Thompson River	5.206	0.731	Medium
102801021005	Fox Creek-Sugar Creek	5.235	0.822	Medium
102801021006	Racoon Creek	5.239	0.795	Medium
102801021007	Sugar Creek	5.253	0.795	Medium
102801021008	Lost Creek-Thompson River	5.108	0.751	Low
102801021101	Upper Muddy Creek	5.523	0.697	High
102801021102	Middle Muddy Creek	5.111	0.617	Low
102801021103	Lower Muddy Creek	5.666	0.753	High

HUC-12	HUC-12 name	Nitrogen (lbs/year)/acre	Phosphorus (lbs/year)/acre	Rank
102801021201	East and West Forks Honey Creek	5.904	0.642	High
102801021202	Upper Honey Creek	6.109	0.709	High
102801021203	Lower Honey Creek	5.795	0.918	High
102801021301	Headwaters No Creek	6.250	0.674	High
102801021302	Crooked Creek	5.770	0.870	High
102801021303	No Creek	5.475	0.827	Medium
102801021401	Hickory Creek	5.178	0.723	Medium
102801021402	Gees Creek	4.861	0.649	Low
102801021403	Wolf Creek-Thompson River	4.674	0.729	Low
102801021404	Thompson River	4.545	0.672	Low

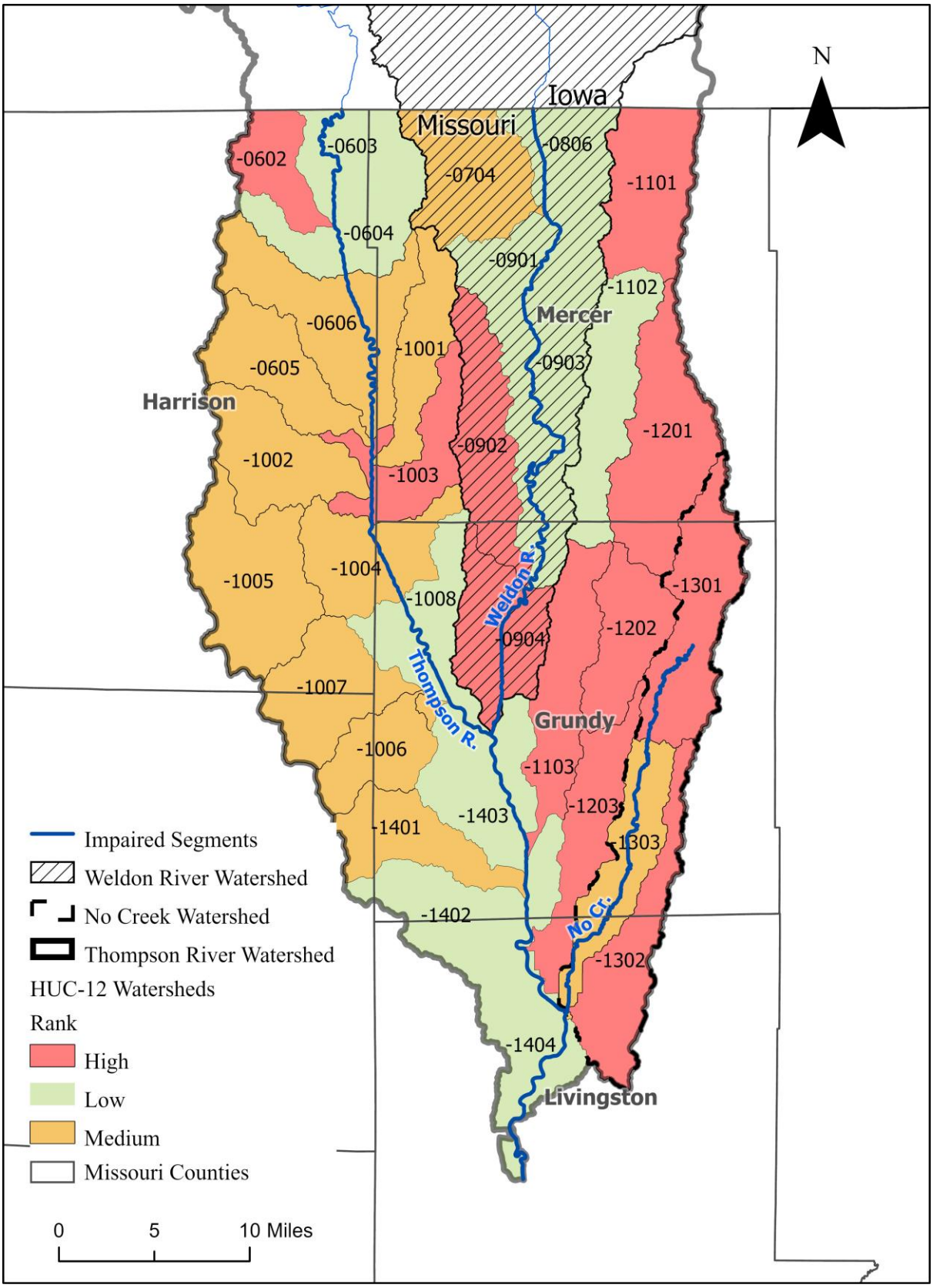


Figure 4. Relative Nitrogen and Phosphorus Loading by HUC-12 Watershed

7.2 Nonpoint Source Management Activities Previously Implemented

The Missouri Soil and Water Conservation Program provides cost-share programs to support the reduction of *E. coli* loading in agricultural watersheds. Cost-share projects implemented in the Thompson River watershed between 2016 and 2021 are summarized in Table 18. Many of the previously implemented best management practices are intended to reduce erosion. Erosion reduction practices also reduce *E. coli* and nutrient loading.

Table 18. Nonpoint Source Best Management Practices Implemented Between 2016 and 2021

HUC-12	Practice Name	Number of Practices	Total Acres
102801020602	Cover Crop	5	230.0
	Impoundment	2	52.4
	Permanent Vegetative Cover Establishment	1	62.2
	Sediment Retention, Erosion, or Water Control Structure	2	6.0
	Terrace System with Tile	1	33.8
	Total	**11**	**384.4**
102801020603	Cover Crop	5	396.5
	Impoundment	2	89.7
	Sediment Retention, Erosion, or Water Control Structure	2	44.8
	Stream Protection	1	3.3
	Total	**10**	**534.3**
102801020604	Cover Crop	9	373.3
	Diversion	1	13.2
	Grazing System Water Development	2	54.0
	Impoundment	6	90.4
	Permanent Vegetative Cover Establishment	3	57.3
	Sediment Retention, Erosion, or Water Control Structure	1	6.5
	Terrace System with Tile	3	10.8
	Well Decommissioning	1	0.0
	Total	**26**	**605.5**
102801020605	Cover Crop	3	404.6
	Impoundment	7	130.5
	Livestock Exclusion	1	2.0
	Permanent Vegetative Cover Establishment	1	2.1
	Sediment Retention, Erosion, or Water Control Structure	3	39.0
	Terrace System with Tile	3	61.3
	Total	**18**	**639.5**
102801020606	Cover Crop	7	350.3
	Impoundment	3	47.9
	Livestock Exclusion	1	2.0
	Permanent Vegetative Cover Establishment	1	20.6
	Sediment Retention, Erosion, or Water Control Structure	2	24.9
	Terrace System with Tile	3	41.2
	Total	**17**	**486.9**
102801020704	Impoundment	6	122
	Livestock Exclusion	1	0.93
	Permanent Vegetative Cover Establishment	2	125.4
	Sediment Retention, Erosion, or Water Control Structure	1	23.7

HUC-12	Practice Name	Number of Practices	Total Acres
	Stream Protection	3	47.8
	Total	**13**	**319.9**
102801020806	Cover Crop	2	46.6
	Impoundment	1	5.5
	Sediment Retention, Erosion, or Water Control Structure	1	7.1
	Total	**4**	**59.2**
102801020901	Cover Crop	3	71.3
	Impoundment	3	39.7
	Permanent Vegetative Cover Establishment	2	110.5
	Sediment Retention, Erosion, or Water Control Structure	1	3.9
	Terrace System with Tile	1	34.1
	Well Decommissioning	2	0.0
	Total	**12**	**259.5**
102801020902	Cover Crop	27	2,800.1
	Diversion	1	39.8
	Field Border	2	323.9
	Impoundment	3	32.4
	Sediment Retention, Erosion, or Water Control Structure	3	14.5
	Terrace System with Tile	4	27.2
	Total	**40**	**3,237.9**
102801020903	Cover Crop	23	1,005.5
	Impoundment	1	11.2
	Livestock Exclusion	1	0.7
	Permanent Vegetative Cover Establishment	1	17.0
	Sediment Retention, Erosion, or Water Control Structure	1	51.5
	Total	**27**	**1,085.9**
102801020904	Cover Crop	12	1,256.1
	Impoundment	5	70.7
	Permanent Vegetative Cover Establishment	1	9.0
	Sediment Retention, Erosion, or Water Control Structure	2	23.7
	Terrace System with Tile	4	47.8
	Total	**24**	**1,407.3**
102801021001	Cover Crop	3	118.8
	Impoundment	8	89.5
	Permanent Vegetative Cover Establishment	3	98.4
	Sediment Retention, Erosion, or Water Control Structure	5	24.8
	Stream Protection	1	25.0
	Terrace System with Tile	1	24.6
	Total	**21**	**381.1**
102801021002	Cover Crop	8	475.6
	Diversion	2	26.0
	Field Border	2	44.0
	Impoundment	2	15.5
	Livestock Exclusion	2	43.6
	Permanent Vegetative Cover Establishment	2	29.2
	Sediment Retention, Erosion, or Water Control Structure	4	57.5

HUC-12	Practice Name	Number of Practices	Total Acres
	Terrace System with Tile	1	16.2
	Total	**23**	**707.6**
102801021003	Cover Crop	21	1,896.67
	Field Border	2	107.0
	Impoundment	2	55.1
	Sediment Retention, Erosion, or Water Control Structure	4	126.9
	Well Decommissioning	2	0.0
	Total	**31**	**2,185.7**
102801021004	Cover Crop	7	586.81
	Impoundment	2	87.5
	Livestock Exclusion	2	5.0
	Sediment Retention, Erosion, or Water Control Structure	3	145.3
	Terrace System with Tile	1	19.9
	Total	**15**	**844.5**
102801021005	Cover Crop	54	4,066.5
	Diversion	1	26.5
	Field Border	1	0.0
	Impoundment	9	116.9
	Permanent Vegetative Cover Establishment	3	87.3
	Sediment Retention, Erosion, or Water Control Structure	17	281.3
	Terrace System with Tile	27	437.6
	Well Decommissioning	3	0.0
	Total	**115**	**5,016.1**
102801021006	Cover Crop	29	2,044.9
	Impoundment	3	95.4
	Sediment Retention, Erosion, or Water Control Structure	1	5.9
	Spring Development	1	0
	Terrace System with Tile	7	1,18.6
	Total	**41**	**2,264.8**
102801021007	Cover Crop	19	1,433.9
	Diversion	4	47
	Impoundment	4	84.3
	Permanent Vegetative Cover Establishment	2	112.2
	Sediment Retention, Erosion, or Water Control Structure	2	51.2
	Terrace System with Tile	7	114
	Well Decommissioning	2	0
	Total	**40**	**1,842.6**
102801021008	Cover Crop	17	1,314.1
	Impoundment	9	102.9
	Sediment Retention, Erosion, or Water Control Structure	3	50.7
	Terrace System with Tile	5	104
	Total	**34**	**1,571.7**
102801021101	Cover Crop	8	618.1
	Impoundment	8	97.6
	Permanent Vegetative Cover Establishment	8	203.3
	Sediment Retention, Erosion, or Water Control Structure	1	4.9

HUC-12	Practice Name	Number of Practices	Total Acres
	Stream Protection	1	8.6
	Terrace System with Tile	2	18.2
	Well Decommissioning	3	0
	Total	**31**	**950.7**
102801021102	Cover Crop	13	1,913.2
	Impoundment	5	47.4
	Permanent Vegetative Cover Establishment	7	244.3
	Sediment Retention, Erosion, or Water Control Structure	3	17.1
	Stream Protection	1	4.3
	Terrace System with Tile	2	19.3
	Well Decommissioning	1	0.0
	Total	**32**	**2,245.6**
102801021103	Cover Crop	4	305.1
	Diversion	1	9.0
	Impoundment	4	107.7
	Terrace System with Tile	7	90.2
	Total	**16**	**512.0**
102801021201	Cover Crop	65	4,154.7
	Field Border	2	520.2
	Impoundment	16	298.2
	Permanent Vegetative Cover Establishment	2	36.7
	Sediment Retention, Erosion, or Water Control Structure	10	115.6
	Stream Protection	3	21.8
	Terrace System with Tile	4	33
	Well Decommissioning	4	0
	Total	**106**	**5,180.3**
102801021202	Cover Crop	22	1,595.4
	Diversion	1	8.2
	Impoundment	9	332.4
	Permanent Vegetative Cover Establishment	1	18.5
	Sediment Retention, Erosion, or Water Control Structure	3	34.5
	Terrace System with Tile	16	223.1
	Total	**52**	**2,212.1**
102801021203	Cover Crop	13	1,363.7
	Impoundment	1	29.4
	Sediment Retention, Erosion, or Water Control Structure	1	8.3
	Terrace System with Tile	15	277.7
	Total	**30**	**1,679.1**
102801021301	Cover Crop	17	1,152.1
	Grazing System Water Development	9	542
	Impoundment	7	177
	Sediment Retention, Erosion, or Water Control Structure	6	70.1
	Terrace System with Tile	12	226
	Total	**51**	**2,167.2**
102801021302	Cover Crop	32	2,580.2
	Diversion	3	32.7

HUC-12	Practice Name	Number of Practices	Total Acres
	Impoundment	2	17.0
	Permanent Vegetative Cover Establishment	1	22.6
	Sediment Retention, Erosion, or Water Control Structure	3	50.0
	Terrace System with Tile	22	460.4
	Total	**63**	**3,162.9**
102801021303	Cover Crop	7	388.8
	Diversion	1	21.0
	Impoundment	3	85.0
	Nutrient Management	1	69.5
	Sediment Retention, Erosion, or Water Control Structure	10	118.7
	Terrace System with Tile	16	239.0
	Total	**38**	**922.0**
102801021401	Cover Crop	17	1,428.3
	Diversion	1	8.0
	Impoundment	7	124.6
	Sediment Retention, Erosion, or Water Control Structure	3	52.9
	Sod Waterway	2	69.0
	Terrace System with Tile	14	258.8
	Total	**44**	**1,941.6**
102801021402	Cover Crop	12	528.3
	Impoundment	1	7.6
	Permanent Vegetative Cover Establishment	1	9.3
	Sediment Retention, Erosion, or Water Control Structure	1	43.0
	Sod Waterway	1	106.0
	Spring Development	1	0.0
	Stream Protection	1	29.8
	Terrace System with Tile	5	40.1
	Total	**23**	**764.1**
102801021403	Cover Crop	5	428.5
	Diversion	1	24
	Impoundment	9	182.7
	Sediment Retention, Erosion, or Water Control Structure	2	8.6
	Terrace System with Tile	7	130.4
	Total	**24**	**774.2**
102801021404	Cover Crop	2	44.7
	Impoundment	2	27.0
	Permanent Vegetative Cover Establishment	1	17.1
	Terrace System with Tile	2	32.0
	Total	**7**	**120.8**
	Grand Total	**1039**	**46,466.9**

7.3 Potential Nonpoint Source Management Measures and Expected Load Reductions

Nonpoint source management measures should focus primarily on reducing *E. coli* and nutrient loading from grassland and pasture lands because loading is typically higher from these areas. Suggested nonpoint source management measures are summarized in the following sections.

7.3.1 Riparian Buffers

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in erosion reduction, as well as the detention, removal, and assimilation of pollutants in runoff. Therefore, a stream with good riparian cover is better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Shade provided by riparian corridors is also important because it helps to keep water cooler (cold water holds more oxygen) and reduces temperature variation that stresses aquatic life especially during the critical low flows that typically occur in July and August. Approximately 35 percent of the riparian corridors in the Thompson River watershed are covered by either cropland or pastureland. Riparian corridors that lack woody vegetation should be prioritized for riparian restoration.

7.3.2 Streambank Stabilization

Streambank stabilization measures also reduce erosion. Such measures may include the installation of live stakes, coconut fiber rolls and mesh, coir rolls, bank terracing, large woody debris, and large boulders to support streambanks and reduce erosion. Integrating shrub and tree planting with other bank stabilization measures results in long-term stabilization as the vegetative roots expand and provide further soil stability. Many resources are available to guide streambank stabilization design for specific conditions. A good initial reference is the *Army Corps of Engineers Streambank and Shoreline Protection Manual* (https://www.lrc.usace.army.mil/Portals/36/docs/regulatory/pdf/StrmManual.pdf).

A study of bank stabilization on the Cedar River in Nebraska[11] (Naisargi and Mittelstet 2017) found the average streambank erosion rate before stabilization was approximately 1.5 ft^2/ft and was reduced to 0.5 ft^2/ft after stabilization measures were implemented.

7.3.3 Livestock Exclusion

Livestock that have access to streams reduce streamside vegetation, increase barren areas, and contribute *E. coli* and nutrients directly to streams. In addition, compaction from animals contributes to poor quality aquatic habitat because the interstitial spaces in stream substrate are eliminated. Excluding livestock from streams is another way to improve water quality and aquatic habitat in the Thompson River watershed.

[11] The Cedar River watershed is located in North Central Nebraska. The western half of the watershed is mainly grassland and sand dunes in the Sand Hills, whereas the eastern half is predominantly cropland.

7.3.4 Nutrient Management

Nutrient management is the most effective strategy for reducing *E. coli* and nutrient loading from agricultural lands to streams. The *Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard* is available online at: dnr.mo.gov/node/1501. The technical standard describes soil and manure testing protocols, manure application criteria including required setback distances from streams, and monitoring requirements. Department staff are available to assist CAFO operators in the development of effective nutrient management plans.

The primary goal of nutrient management is to promote biomass productivity that provides profit for producers while minimizing negative environmental impacts. Over-application of nitrogen and phosphorus above the crop needs will cause these nutrients to accumulate in the soil and increase the potential for losses to the environment. Nutrient management planning minimizes the transport of *E. coli*, nitrogen, and phosphorus to surface and ground water by optimizing fertilizer application rates, timing, and placement, as well as accounting for all sources of nutrients.

Nutrient management plans may be eligible for cost-share programs through the Soil and Water Conservation Program. Nutrient Management Plans should be developed in accordance with the NRCS Standards and Specifications for Nutrient Management (590). Landowner assistance is available through the Harrison, Mercer, Daviess, Grundy, and Livingston County Soil and Water Conservation Districts.

In general, the following are required to begin nutrient management planning:

- Soil samples, based on a 7-inch depth, shall be taken once every four years, as a minimum, to monitor the phosphorus, potassium, pH and organic matter levels and adjust nutrient application rates as needed. The pH of the soil is important because it has a direct effect on nutrient availability. Follow Iowa State University recommendations and soil testing procedures to develop a crop budget for determining crop nutrient needs. Nitrate testing using the late spring nitrate test and fall corn stalk test can be used to monitor the nitrogen management program. Soil pH levels shall be maintained near 6.5 for corn and soybeans and 6.9 for alfalfa.
- Manure analysis could be completed on an annual basis for percent of solids, total N, organic N, NH_4, P_2O_5, K_2O and pH. A more realistic nutrient content can be obtained by using the averages of three or more analysis.
- Soil tests and realistic yield potentials will be used to determine the application rate of manure so as to supply most of the crop nutrient needs through the manure and legume credits. No additional commercial phosphate or potash will be applied on soils testing high or very high in phosphorus and potassium (K). On these fields additional commercial nitrogen will be applied as needed. This will optimize crop yield potential while minimizing nutrient runoff and nitrogen leaching.
- Sensitive areas: Commercial nutrients, manure and organic by-products shall not be applied to frozen, snow covered ground or saturated soil on slopes greater than five percent unless erosion is controlled. Manure and organic by-products shall not be applied within 200 ft. of a stream, lake, agricultural drainage well, or sinkhole unless injected or incorporated within 24 hours.

- Risk Analysis: The phosphorus index will be used to determine fields that are a high risk for phosphorus losses. Conservation and/or best management practices will be used to reduce the potential for phosphorus movement off site. Soil tests will be taken every four years to determine changes in phosphorus levels.

The plan should receive periodic review to determine if adjustments or modifications are needed. At a minimum the plan will be reviewed and revised with each soil test cycle.

7.3.5 Cover Crops

Planting cover crops rather than leaving cultivated cropland barren has both economic and environmental benefits. Legume cover crops can reduce fertilizer costs because of their symbiotic relationship with soil bacteria. Specific bacteria reside within nodules of the roots of legumes, such as vetch and clover, and convert nitrogen gas from the atmosphere into soil nitrogen that crops can use. This biological nitrogen fixation reduces the amount of fertilizer that needs to be purchased and applied. Applying less fertilizer to the topsoil means reduced transport of nutrients to water bodies in the watershed. Cover crops also reduce erosion by holding soil in place and reducing top-soil crusting. The plant material left behind after cover-cropping increases water infiltration and reduces evaporation. This reduces the amount of nutrient-laden runoff, and the amount of water needed for irrigation. Moisture retention by decaying plant material also helps soils be more resilient to periodic drought conditions.

A study conducted by Zhu et al. (1989) as cited in Sharpley and Smith (1991) found that planting common chickweed, Canada bluegrass, and downy brome on Missouri soybean fields decreased water runoff by an average 44 percent. The study found that nitrogen (as nitrate) loss was reduced by an average 75 percent and soluble phosphorus runoff was reduced by an average 37 percent. Sharpley and Smith (1991) found that planting ryegrass or wheat on peanut crops for 6 months of the year reduced soil loss by an average of 83 percent.

The Missouri Parks, Soils, and Water sales tax program provides grants to cover up to 75 percent of the cost of planting cover crops, alternative crops, and vegetative buffer zones (field borders). The grants are administered through the Missouri Soil and Water Conservation Program.

7.3.6 Prairie Strips

Implementing prairie strips in croplands can reduce both soil erosion and nutrient runoff. Prairie strips include edge-of-field filter strips and infield contour buffer strips. Infield contour buffer strips' primary purpose is to reduce erosion, while edge of the field filter strips primary purpose is to filter excess nutrients and animal waste. A study conducted in Iowa found that converting 10 percent of crop field to prairie filter strips reduced average annual nitrate, total nitrogen, and total phosphorous concentrations by 35, 73, and 82 percent respectively (Zhou et al. 2014). Grants provided by the Missouri Parks, Soils, and Water sales tax program can cover up to 75 percent of the cost of implementing prairie strips.

7.3.7 Field Borders

Field borders can provide a number of conservation benefits, such as reducing soil erosion from wind and water, protecting soil and water quality and providing habitat for wildlife. These habitats, located at the edges of crop fields, can also serve to connect other buffer practices and habitats within the agricultural landscape. The U.S. Department of Agriculture's Farm Service Agency (FSA) runs a program called the Continuous Sign-up Conservation Reserve Program (CCRP) that provides farmers with rental payments on land set-aside for conservation buffers for a period of 10-15 years. Cost-share payments are also made available to help farmers with the financial burden of establishing the buffers.

8. Public Outreach

Public outreach is a key component of any watershed management plan. Measures to reduce pollutant loading from unregulated nonpoint source areas are implemented voluntarily through cooperation between citizen groups, landowners, government agencies, and funding entities. Support for nonpoint source reduction plans is generated through education and outreach activities designed to inform the public about water quality issues and what can be done to reduce pollutant loading in watersheds. The U.S. Environmental Protection Agency, U.S. Department of Agriculture, Natural Resources Conservation Service, Soil and Water Conservation Districts, Missouri Department of Natural Resources, Missouri Department of Conservation, University of Missouri Extension, and local governments produce educational materials and make them available on their websites. Staff within these agencies are available to assist with public education and provide technical support for watershed plan development.

The following are some activities recommended to develop support and participation for watershed stewardship.

1. Hold meetings and other outreach events to inform private landowners of the available technical support and financial incentives for implementing pollutant reduction strategies.
2. Attend livestock auctions and demonstrations in the local community, and hand-out literature explaining the available technical support and financial incentives for implementing pollutant reduction strategies.
3. Develop small-scale demonstrations of pollutant reduction strategies.
4. Implement a public awareness campaign regarding water quality with public service announcements.
5. Host local watershed festivals.

9. Measurable Milestones

Measurable milestones outline time frames for the incremental implementation of pollutant reduction strategies. Attainable milestones should be established based on available funding and stakeholder participation. For point sources, milestones may be integrated into permits as schedules of compliance to allow time to plan, fund, and construct facility upgrades or implement adaptive management. Nonpoint source pollutant reduction plans should include milestones for public outreach, attaining funding, and the implementation of chosen nonpoint source management measures. In addition, monitoring and adaptive management plans should be developed for vegetation restoration areas to ensure that plants are healthy and will grow and develop into effective *E. coli* and nutrient attenuation areas. Plans that are developed to procure Section 319 subgrants must be renewed every five years to stay eligible for funding. It is good general practice to develop measurable watershed management milestones on 5-year timeframes. Riparian buffer restoration monitoring and adaptive management plans should include annual monitoring and assessment of plant growth and development with a 5 to 7-year goal of vegetation maturity. The annual evaluations allow for adaptive management to ensure that efforts are successful.

10. Cost-Benefit

Cost-benefit analyses should be conducted during the watershed management planning process to determine the most efficient investments of time, effort, and supplies. Upgrades to point source facilities should consider both the immediate and necessary future capacity of the facility and should be designed based on the best available affordable technology. Costs associated with nutrient management plan implementation and cover crops are relatively minimal because many of the practices are already integrated into the farming system and substantial cost savings are achieved through reducing the need for manure application and chemical fertilizers. Streambank stabilization is the most expensive pollutant reduction strategy but can be prioritized to key areas to stabilize highly erosive streambanks for the benefit of water quality in all downstream waters.

11. Cooperating Agencies and Funding Sources

Reducing pollutant loading to achieve TMDLs often requires participation and cooperation from government agencies. TMDLs are written to meet applicable water quality standards per federal regulations at 40 CFR 130.7(c)(1). As a result, they are developed without considering citizen interest, available treatment technologies, or costs associated with nonpoint source management measures. Public service staff can assist with outreach and education, provide technical guidance, and direct interested parties to potential funding sources. Some of the available agencies and

organizations and their potential roles, including funding avenues, are listed in Table 19. The list is not exhaustive and not intended to compel participation from any organization nor is it meant to exclude any who are not listed but gives a general idea of responsibilities and potential roles in watershed management. The most commonly used sources of funding are low-interest loans or grants through the State Revolving Fund, Section 319 subgrants, and cost-share practices through the state's Soil and Water Conservation Program.

Table 19. Agency Roles and Funding Options

Agency and Roles	Funding Options
US Department of Agriculture, Natural Resources Conservation Service https://www.nrcs.usda.gov/wps/portal/nrcs/site/mo/home/	
Financial assistance and incentives to implement voluntary best management practices	Environmental Quality Incentives Program (EQIP) Regional Conservation Partnership Program (RCPP) Conservation Stewardship Program (CSP) Agricultural Conservation Easement Program (ACEP)
US Department of Agriculture's Farm Service Agency (FSA) https://www.fsa.usda.gov/	
Administers a program called the Continuous Sign-up Conservation Reserve Program (CCRP) that provides farmers with rental payments on land set-aside for conservation buffers for a period of 10-15 years. Cost-share payments are also made available to help farmers with the financial burden of establishing the buffers.	Continuous Sign-up Conservation Reserve Program (CCRP)
Missouri Department of Natural Resources dnr.mo.gov/	
Water Protection Program dnr.mo.gov/about-us/division-environmental-quality/water-protection-program Implements federal Clean Water Act regulations including: enforcing National Pollutant Discharge Elimination System (NPDES) regulations through point source facility operation permits, establishing Water Quality Standards, identifying impaired water bodies, and developing TMDLs.	Free volunteer water quality monitoring training and tools

Agency and Roles	Funding Options
Financial Assistance Center https://dnr.mo.gov/water/business-industry-other-entities/financial-opportunities/financial-assistance-center Provides technical guidance for publicly-owned treatment works and administers low-interest long-term loans to assist with technology and capacity upgrades. The Clean Water State Revolving Fund provides subsidized loans to municipalities, counties, public sewer districts, and political subdivisions for wastewater infrastructure projects. Loans may be paired with grant funds for qualifying communities. Information on the Department's grant policy is available online at dnr.mo.gov/water/business-industry-other-entities/financial-opportunities/financial-assistance-center-srf/wastewater/ Eligible projects include new construction or improvement of existing facilities.	Clean Water State Revolving Fund
Soil and Water Conservation Program dnr.mo.gov/land-geology/soil-water-conservation/The Soil and Water Conservation Program (SWCP) provides financial incentives to landowners to implement practices that help prevent soil erosion and protect water quality. The program offers cost-share practices through its county conservation districts. Landowners may receive up to 75 percent reimbursement of the estimated cost of a practice through the program. The primary funding for cost-share practices from the Soil and Water Conservation Program comes from the one-tenth-of-one percent Parks, Soils, and Water Sales Tax.	SWCP cost-share
Section 319 Nonpoint Source Program dnr.mo.gov/water/what-were-doing/nonpoint-source-pollution-section-319/ Provides assistance with the development of watershed management plans and administers Section 319 subgrants for plan development and implementation.	Section 319 subgrants
Missouri Department of Conservation https://mdc.mo.gov/	
Offers a number of grant and cost-share options including Community Conservation Grant and Land Conservation Partnership Grant mdc.mo.gov/community-conservation/community-conservation-funding-opportunities/. Provides outreach, education, and technical guidance for stream and watershed management issues. Maintains Missouri Conservation lands. Issues permits for fishing and hunting.	Community Conservation Grant and Land Conservation Partnership Grant Free volunteer water quality monitoring training and tools
Missouri Agricultural and Small Business Development Authority agriculture.mo.gov/abd/financial/awloanprg.php	

Agency and Roles	Funding Options
Offers an Animal Waste Treatment System Loan Program in cooperation with the Clean Water State Revolving Fund. Animal Waste Treatment Loans Program may finance eligible animal waste treatment systems for independent livestock and poultry producers with operations of less than 1,000 animals. Eligible costs include storage structures, land, dedicated equipment, flush systems, composters, and more.	Clean Water State Revolving Fund
University of Missouri Extension https://extension2.missouri.edu/	
Provides guidance for farm management including crop resilience, pond health, and livestock care.	Free information and assistance
County Soil and Water Conservation Districts https://mosoilandwater.land/	
Provides guidance and assistance with the development of nutrient management plans and procurement of funding from the state cost-share program.	Free information and assistance with grant applications
Online Databases of Additional Funding Sources	
▪ Wichita State University, Environmental Finance Center (EFC) Missouri Healthy Watershed Funding Search Tool https://www.wichita.edu/academics/fairmount_college_of_liberal_arts_and_sciences/hugowall/efc/news/meramec-funding-sources-landing-page.php ▪ Catalog of Federal Funding https://www.epa.gov/waterdata/catalog-federal-funding ▪ EPA Nonpoint Source Funding Opportunities http://water.epa.gov/polwaste/nps/funding.cfm ▪ Environmental Justice Grants https://www.epa.gov/environmentaljustice/environmental-justice-grants-and-resources ▪ Grants.gov http://www.grants.gov	

12. Conclusion

The ultimate goal of pollutant reduction strategies is to meet Missouri Water Quality Standards through the protection of aquatic life in warm water habitats, whole-body contact recreation, and other beneficial uses. Implementation strategies should follow an adaptive approach that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. Implementation efforts are expected to occur over a number of years, but within the schedules established in state operating permits and watershed management plans. Success in achieving water quality standards will be determined by the Department through biennial assessments of water quality compliance as required by Sections 305(b) and 303(d) of the federal Clean Water Act.

The Department maintains administrative records for the Thompson River, Weldon River, and No Creek TMDL. The records contain the TMDL document, this implementation strategies document,

and any studies, data, or calculations upon which loading targets are based. This information is available upon request to the Department at dnr.mo.gov/sunshinerequests.htm. Any request for information about TMDLs will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests.

This implementation strategies document is scheduled for a 45-day public notice and comment period in conjunction with the comment period for the Thompson River, Weldon River, and No Creek *E. coli* TMDL. Any comments received, as well as the Department's responses to those comments, will be maintained on file with the Department and posted online at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls. The Department maintains an email distribution list for notifying subscribers of significant TMDL updates or activities. Those interested in subscribing to these TMDL updates can submit their email address using the online form at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

13. References

Federal Geographic Data Committee (FGDC). 2003. FGDC Proposal, Version 1.1, Federal Standards for Delineation of Hydrologic Unit Boundaries. December 23, 2003.

Guber, A. K., Shelton, D. R., Pachepsky, Y. A., Sadeghi, A. M., & Sikora, L. J. (2006). Rainfall-induced release of fecal coliforms and other manure constituents: comparison and modeling. *Applied and Environmental Microbiology, 72*(12), 7531-7539.

MoRAP (Missouri Resource Assessment Partnership). 2005. A gap analysis for riverine ecosystems of Missouri. Final report, submitted to the USGS national gap analysis program. 1675pp.

Naisargi, Dave and Mittelstet, Aaron, R. 2017. Quantifying Effectiveness of Streambank Stabilization Practices on Cedar River, Nebraska. *Water* 9:930. doi:10.3390/w9120930.

NRCS (Natural Resources Conservation Service). 2013. Nutrient Management Plan Narrative with Livestock. [Online WWW] Available URL: https://nerc.org › documents › comprehensive_nutrient_management [Accessed 2021].

Sharpley, A.N. and Smith, S.J. 1991. Effects of cover crops on surface water quality. *Surface Water Impacts.* Available URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.596.3210&rep=rep1&type=pdf [Accessed February 2021].

Sutton, Alan L. 1990. Animal Agriculture's Effect on Water Quality Pastures and Feedlots. WQ-7. Purdue University Extension. [Online WWW]. Available URL: http://www.ces.purdue.edu/extmedia/wq/wq-7.htmL [Accessed 23 Dec. 2011].

Zhou, X., Helmers, M. J., Asbjornsen, H., Kolka, R., Tomer, M. D., & Cruse, R. M. 2014. Nutrient removal by prairie filter strips in agricultural landscapes. *Journal of Soil and Water Conservation*, *69*(1), 54-64.

Zhu, J.C., Gantzer, C.J., Anderson, S.H., Alberts E.E., and Beuselinck, P.R. 1989. Runoff, soil, and dissolved nutrient losses from no-till soybean with winter cover crops. *Soil Science Society of America Journal.* 53:1210-1214.

Appendix A
Nine Key Elements Critical to a Watershed Management Plan

a. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan, as discussed in item (b) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).
b. An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded streambanks).
c. A description of the nonpoint source management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.
d. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, U.S. Department of Agriculture's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.
e. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.
f. A schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
g. A description of interim, measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a nonpoint source TMDL has been established, whether the nonpoint source TMDL needs to be revised.
i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Appendix B.
Targeted Participants and Potential Roles in Implementation

The Department implements TMDL targets for point sources through the Missouri State Operating Permit program. For nonpoint sources, private landowners and citizen groups voluntarily implement water quality improvement projects and cost-share practices, which may be funded in part by grants or subgrants from the Department's Section 319 Nonpoint Source Implementation Program and the Soil and Water Conservation Program. Local governments, citizen groups, and individuals who have an interest in improving water quality in their communities may implement additional water quality improvement actions. Successfully meeting the goals of a TMDL often requires participation and cooperation from various parties within a watershed. Participant roles range from technical support to actual on-the-ground implementation of BMPs. Groups and agencies that may potentially be involved in the TMDL implementation process are identified below along with descriptions of their possible roles. This list is not exhaustive and not intended to compel participation from any organizations; nor is it meant to exclude those who are not listed, but may be interested in participating.

- Department of Natural Resources
    - Administers statutory authorities granted by Missouri clean water law
    - Ensures permits issued in the watershed are consistent with the assumptions and requirements of TMDL wasteload allocations (the allowable point source load) o Provides compliance assistance to regulated entities
    - Provides technical support to locally-led watershed groups
    - Serves as a potential source of financial assistance for watershed plan development and BMP implementation through Sections 319(h) and 604(b) grants, or through Soil and Water Program cost-share practices
    - Serves as a potential source of financial assistance for infrastructure improvements through low-interest State Revolving Fund loans
    - Assesses attainment of water quality standards on a biennial basis for Clean Water Act Sections 303(d) and 305(b) reporting Implementation Strategies for Thompson River, Weldon River, and No Creek
    - Provides education and training to volunteers through the Missouri Stream Team Program
    - Provides technical assistance for market-based approaches to compliance such as water quality trading
- County Soil and Water Conservation Districts
    - Provide financial incentives to agricultural producers to implement conservation practices that help prevent soil erosion and protect water quality
    - Provide technical assistance with design, implementation, and maintenance of conservation practices
- University of Missouri Extension
    - Provides technical assistance for addressing nonpoint source and watershed management issues
    - Assists with organizing locally led watershed groups
- Missouri Department of Conservation
    - Provides technical assistance with stream and watershed management issues
    - Promotes maintenance and reestablishment of stable streambanks and functional riparian corridors

- Missouri Department of Health and Senior Services
    - Provides technical assistance pertaining to onsite wastewater treatment systems (i.e., septic)
- County Health Departments
    - Provide technical assistance pertaining to onsite wastewater treatment systems
- Locally led watershed groups
    - Develop and implement Section 319-funded nine key element watershed-based plans (See Appendix A)
    - Identify critical areas at a local level
    - Implement BMPs to reduce nonpoint source pollutant loading
    - Provide public education and outreach
- Stream Team volunteers
    - Collect screening level water quality data (i.e., dissolved oxygen and biological monitoring) through the Volunteer Water Quality Monitoring program
    - Provide stewardship, advocacy, and education.